Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

PREVENTION OF ELECTROLYSIS TROUBLES IN UNDERGROUND PIPE STRUCTURES[1]

By E. B. Stewart[2]

The subject of electrolysis upon underground pipe structures is no doubt of more or less interest to all water works men, and any new causes for it, or features not generally understood, will doubtless claim your attention.

The object of this paper, therefore, is to discuss in a general way the electrolytic problems most generally encountered by pipe owning companies and the methods of mitigating them.

Electrolysis may be defined as a process by which chemical changes are caused by an electric current independent of any heating effect. In order that electrolysis may occur, there must be a flow of electric current through a conducting liquid from one terminal to another, and the conducting liquid must be a chemical compound or solution which can be altered by the action of the electric current. The injury resulting from electrolysis is brought about by removal of part of the metal when the stray current leaves the metal to go into the soil. That is, the stray current can flow from the metal into the soil only by taking a part of the metal with it.

The majority of the street railways of the country are operated on the single overhead-trolley plan, with the electric current flowing onto the rails through the car wheels, after it has passed through the car motors. If the rails of an electric road are not insulated from the earth, they will not carry the total current all the way back to the power house. A part of the current will branch off into the earth and flow through the surrounding pipe structures, returning to the rails at certain fixed points. This branching off of current depends upon the conductivity of the earth, and the character and relative position of the metallic masses in the earth with respect to the rails.

---

[1] Read before the California Section Meeting, October 1, 1921.

[2] Electrical Engineer, East Bay Water Co., Oakland, Calif.

Underground waters, rivers, lakes, etc., influence more or less the path of earth currents, but extensive pipe systems of good conductors have a still greater influence.

The return current will be distributed through all the conductors in parallel with the rails in the order of the divided circuits; i.e. the strength of the current in all possible paths in parallel will be inversely proportional to the resistance in each path.

The interchange of current between rails and pipes have certain earth resistances to overcome in passing from rails to nearby pipes and vice versa. These resistances are of primary importance in determining the extent and seriousness of electrolytic corrosion. Obviously no electrolytic corrosion would occur should the resistance between rails and pipes be zero, and likewise no trouble would occur should the resistance be infinitely high. Hence resistances between these extremes determine the extent and seriousness of electrolytic troubles.

In making an electrolysis survey, the underground pipe system is generally divided into zones known as *Positive*, *Negative* and *Neutral* zones. These zones may be best illustrated by a pipe line parallel with an electric railway from the power house to remote points near the end of the line.

That portion of the track more remote from the power house will be at a potential above the earth, and those portions of the track in the vicinity of the power house will be at a potential below that of the earth. Consequently in the outlying district these currents, after getting into the earth tend to flow as a general rule in the direction of the power house and they gradually accumulate on the pipe line. This area is known as the *Negative Zone.* But when they reach the region near the power house, these currents are again discharged through the earth to the negative railway structure. In this area damage to the pipes most frequently occurs and is known as the *Positive or Danger Zone.*

The neutral zone is that portion of the pipe midway between the power house and the end of the line.

The reason for failures in areas near the power house are more or less clear in a general way to everyone. But the reason for troubles in outlying areas is sometimes more difficult to analyze. In large cities where a number of power stations are operating it is not uncommon for trouble to develop at outlying points between power stations.

Investigation very often develops that these areas are of swampy earth of very low conductivity and perhaps the rails pass around this region in a somewhat circuitous path. Consequently strong currents are set up as the current shunts from the rails and passes over the affected area seeking the rails again on the opposite side.

Another example may be illustrated by two separate tracks leading from the same power house, and laid out in such a way that the return of one is almost without loss of potential, while the other has considerable loss. In this case all the current will not return through the rails, but part of it will leak across through the earth to the track which is without loss of potential. These currents will accumulate on the pipes running in the same general direction and very often cause destruction in a very short time.

In an effort to reduce or eliminate damage to pipe systems due to stray earth currents, a great many methods are in use.

Those methods which are commonly used are: (1) Surface insulation of pipes; (2) insulating joints; (3) Pipe drainage systems.

Experience has shown that painting or otherwise insulating the surface of pipes by the use of treated paints does not give satisfactory results in areas where the pipes are carrying a large amount of current.

The primary reason for failure of paints under this condition lies in the fact that none of the paints, as you all know, are absolutely impervious to moisture. Consequently, as moisture deteriorates the paint, the paint becomes more conducting for electric current resulting in the formation of more or less gas beneath the coating. As this gas increases in amount and expands, the coating is ruptured, after which the current flow is greatly increased at the point of breakdown resulting in rapid electrolytic corrosion of the pipe.

The system of electrolysis mitigation which is most generally used is the *pipe drainage system*. This system is employed in a variety of forms, the principal ones being as follows:

1. Where direct ties with wires or cables are made between underground pipes and rails.
2. Where uninsulated negative feeders are run from the negative bus to the pipes.
3. Where separate insulated negative feeders are run from the negative bus to underground pipes with resistance taps taken off at intermediate points.

Of these systems the simplest and least extensive system is that of placing direct taps to the pipes in the positive zone. One difficulty of this system of multiple taps lies in the fact that the drop of potential on the pipes is always equal to the potential of the tracks. In other words, if the rails carry a large amount of current, a heavy current will also be produced in the pipes; and in case high resistance joints are encountered a large amount of current will cause heavy leakage around the joint and cause rapid destruction to the pipes. In case of a broken bond in the track system, the amount of current will be considerably increased.

The primary object of drainage by means of uninsulated and insulated negative feeder systems is to keep the pipe drainage system entirely independent of the tracks so that the flow of current around bad joints in the pipes will be less serious.

Fundamentally this system consists of running copper cables from the negative bus parallel with the pipe and tapping to the pipe at frequent intervals.

By the use of resistance taps the current can be controlled so that an equal distribution of current is drawn from the different taps. · In this way a better distribution of the current in the pipe system can be secured and heavy current on the pipes at any point can to a certain extent be avoided, and at the same time reduces to a minimum the cost of copper cable.

Another method of pipe drainage system is that of running different feeder cables from the negative bus and tapping to the pipe at frequent intervals. In this case the feeders are designed so that practically the same amount of current will flow over the feeders from each tap and thereby produce a minimum drop of potential between points at which the taps are connected.

These systems in general practice, however, are seldom employed in the manner as outlined above. The most common practice is to run a copper wire or cable from the negative bus or from the negative return feeder to the pipe. In many cases pipes are connected to the rail near the sub-station, and very often, connections are made to the rails at points considerable distance from the station.

From a personal study of the pipe drainage systems, I am convinced that, while it can, under certain conditions, be used to advantage as a secondary means of lessening trouble, its installation in large city waterworks as a principal means of electrolysis mitigation is an unwise procedure. There are, however, certain special cases where the pipe drainage methods will give fairly good results. This applies particularly to suburban areas where the pipe networks are small.

Under this condition, limited drainage may offer the best means of dealing with the problem, provided there is no appreciable leakage of current from the rails at remote points from the power station.

Bonding to the rails at remote points from the power station is out of the question and should not be resorted to. As an illustration of the disadvantage of this system, we have a case where the pipe line crosses under the rails at a point 2900 feet from the power house. The reason for placing a bond at this point was obviously due to the fact that tests with an indicating meter showed the pipe to be of positive potential to the rail, and the conclusion arrived at, therefore, was that lowering the potential between the pipe and rail would relieve the pipe from electrolytic corrosion. Shortly after placing the bond to the rails at this point, trouble began to develop very close to the point where the bond was connected. No account, however, was taken of the potential of the rails with respect to the earth and also the reversal of current flow from the rails to the pipes during certain changes in the load distribution. The rails at such distances from the power stations are generally always of positive potential to the earth. It is therefore clear that while the bond has removed the discharge of current from the pipe to the rails, the pipe is still positive to the earth; i.e. the pipe is of the same potential to the earth as the rail by reason of the bond connection. Hence the increase of current over the bond produces a heavy discharge of current into the earth causing destruction in a short period of time.

To mitigate a condition of this character involves considerable expense regardless of which plan is to be employed. To attempt to correct this trouble by the proper drainage methods would not only be costly but rather uncertain, especially without certain remedial measures to be taken by the railway people. Fundamentally a drainage wire to accomplish the desired results in this case must be connected very close to the power station which would result in considerably more current being drained from the pipe, and perhaps the increase in drainage would be of such magnitude as to produce little or no change in the potential readings at the rails, hence there would be no benefit derived from this plan. In other words, the closer the drainage wire is connected to the station, the amount of current picked up from the earth will increase in like proportions. And in long drainage wires the size of the wire would necessarily have to be very large in order to maintain a drop of lower potential than the rails.

I believe that the most safe and economical plan to mitigate cases of this character would be to enclose the pipe in a wooden conduit and to fill it with insulating compound. While this plan is costly it serves a double purpose; i.e., the trouble is not only corrected at the rail, but trouble is also minimized to a certain degree, at points remote from the rails due to the fact that insulating the pipe will cause a smaller amount of current to accumulate on the pipe in outlying areas.

Another case of somewhat similar nature is where the pipe runs parallel with the rails and is connected by a drainage wire to the negative bus. This pipe is seriously affected at a remote point where the pipe crosses and runs in very close proximity to the rails.

To mitigate this case by the drainage method would necessitate extending an insulated drainage wire from the negative bus to a point in the affected area. This plan would meet with the same objections as in the previous case.

One of the objections to the pipe drainage system, and this applies to all methods that are in practice, is the fact that they are designed to relieve the symptoms and do little or nothing towards removing the cause of the trouble.

A serious objection to pipe drainage is to be found in the interchange of current between underground structures, resulting from unequal drainage. The drainage of one system of pipes will of course lower its potential with respect to the neighboring metallic structures, thereby tending to injure the latter. This in turn calls for drainage of the injured system, which may damage the first or other structures, and consequently, a system of competitive drainage is established.

This competitive system of drainage requires constant watching, as changes and extensions to the system will establish added points of hazard to the system.

Another difficulty lies in the fact that structures owned by different interests cannot be bonded together except by an agreement between the owners. This very often of itself makes it impossible to apply a comprehensive drainage system to all structures, because of the impossibility of obtaining an agreement of all owners to allow connections to their structures except on condition that another interest assume the liability for any injury which may result from such connections.

In the early stages of the practical working out of the drainage system, the effect of its application is apparently beneficial, reducing danger in positive areas more than it increases it elsewhere.

As the system grows, the load increases; more and heavier bonds become necessary and the current in the pipes may become so great that any further extension of drainage will become a menace to the system. It is largely due to this slow and obscure manner in which trouble develops that has caused this method to be so widely used. That is, the placing of additional bonds between pipes transfers the trouble from where it has been most evident to a new location, where it may require several years to manifest itself anew. Hence the intervening lull which creates a favorable impression is sometimes difficult to dispel even when trouble later occurs.

Another disadvantage of the drainage system is that phase of electrolysis of water pipes which is caused by overdrainage of underground cable systems.

Pipes as a rule are much closer to cable conduits in the ground than they are to rails. In many cases they are but a few inches apart, and in some cases rest directly against the conduit. Under such conditions, where both metals are in wet soil, a low difference of potential, say a few tenths of a volt, is often sufficient to carry current and to cause damage to main or service pipe.

It is a most difficult matter to insulate underground cables even with the most improved type of conduits, so as to prevent current flowing from pipes into them, especially when they are near points where the cables are bonded to railway negatives.

The natural attraction for current flowing upon water or gas mains is directly to the conduit, either from the mains or services. This is the case also with hydrant branches and pipes that pass into side streets. In other words, the cable conduit threads its way between gas and water services as they pass into buildings along a street.

It happens often that pipes are damaged upon streets where there are no tracks. As a matter of fact, the tracks have nothing to do with this feature of electrolysis. In one case where a number of services were found to be leaking, investigation developed that a cable conduit passed directly under them. The services were one-tenth of a volt positive to the cables. In this case the soil was wet clay and the nearness of pipe to the conduit made up for the comparatively low potential to destroy the pipe.

This phase of electrolysis, therefore, shows the necessity of conducting tests between pipes and underground cable systems. Ordinarily this phase of electrolysis would not be suspected, as tests between piping systems and rails would not indicate that such damage was going on.

In laying service pipes, it is advisable to keep the pipes as far away from cable conduits as it is possible to do so, because there is no telling how the currents will flow along the pipes and pass out of them at any convenient point, and generally the point which is nearest the conduit is where the most of the current leaves. If the soil is of sand not much current will pass, but if it is wet clay, then a sufficient amount of current may pass to cause electrolysis corrosion.

The most valuable mitigative measure I believe that can be applied to pipe systems consists in the proper use of insulating joints. We believe the extensive use of such joints should be encouraged in new work and in making repairs.

There are many who criticize this method from the standpoint that current will flow around the joint and cause destruction of the pipe on the positive side of the joint. It is quite true that trouble of this character will arise and cause destruction of the pipe, provided the joints are indiscriminately placed without regard to their frequency, the kind of joints best suited to certain conditions, and the complication arising from the presence of other pipe systems not so insulated. All of these are important factors and must be carefully taken into consideration if adquate protection is to be secured. It should be further understood that insulating joints should be considered as an auxiliary in connection with and supplementary to measures to be applied to railway return systems for reducing stray currents to the lowest possible minimum. While it is not always possible to reduce economically stray current from the rails, it is nevertheless advisable to obtain data to show a fairly good idea of the nature and extent of stray current from the tracks.

As a general rule where a pipe line is laid with about every fourth or fifth joint an insulating joint, the line has such a high electrical resistance that no measurable current flows on the line, although considerable current exists in the earth parallel to the pipe line.

Placing insulating joints at too infrequent intervals is probably responsible for a good deal of disfavor of this system. Obviously if the joints are placed far apart, the long stretch of intervening pipe may pick up considerable current. Since this current must flow out of the pipe as it approaches the insulating joint, serious electrolytic corrosion may occur on the positive side of the joint. The more frequent the joints are placed, the less damage will occur from this source.

In these installations we find that it is necessary to install such insulating joints not only in the positive areas but also in the negative areas where considerable current in the earth parallel to the pipe exists.

In connection with the installation of insulating joints on wrought iron and steel pipes, it has been found necessary to increase the length of the joint by surrounding the joint and pipe with a wood box, leaving a space inside to be filled with insulating compound. The length of the boxes depends upon the resistance and amount of current in the soil.

Enclosing insulating joints does not materially increase the resistance of the joints, but a long insulating joint gives a more even distribution of leakage current than a short joint. A long insulating joint, therefore, is to be preferred when there is considerable potential across the joint or where the resistance of the surrounding soil is very low.

In a number of installations we found considerable current to flow around the joints, due to service pipes being in physical connection with gas services at the houses. This trouble was corrected by inserting an insulation joint at the service meter.

In some cases, however, it was found necessary to install an insulating joint in the service at the main and also a second joint at the meter. The necessary location of these joints must be determined from the results of electrical measurements.

We find the flanged type of joint the most desirable and economical joint to be used on wrought iron and steel pipes. This insulating joint has been made up of a disc of insulating material between the surfaces of the flanges, and placing insulating washers under the bolt heads and nuts. Red or gray fiber has most commonly been used for insulating material.

For cast iron water mains with bell and spigot joints we use a short wooden ring between the inside of the bell and the end of the spigot to prevent metallic contact between the pipe lengths, and then we caulk the joints with cement. The bead of the spigot end of the pipe was removed.

We find that the current in the pipe is considerably reduced by the use of cement joints. This, however, does not in all cases prevent electrolytic corrosion in localities where current can reach, as the pipe by way of laterals or where it is closely adjacent to other conducting structures or when there is leakage from another transverse pipe.

In the practical working out of the various systems of electrolysis protection, the conditions of the railway systems are usually ignored. I believe that a more logical and, at the same time, effective and economical procedure to handle the problem is first to obtain a general working knowledge of the railway systems, that is, a knowledge concerning the load factors of the various power stations, the operating time of each station, and a general knowledge of the leakage currents from the rails. From certain electrical tests it is possible to calculate the probable distribution of the leakage currents from the rails and to locate the places where there is a probability of electrolytic corrosion.

In order to obtain such information with any degree of accuracy, it is quite necessary that cocperation exist between the railway companies and owners of underground utilities.

REFERENCES

Technologic Paper No. 28, Bureau of Standards.
Technologic Paper No. 52, Bureau of Standards.
Carl Mishalke, Stray Current from Electric Railways.